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U.S. NAVY DEPARTMENT. BUREAU OF STEAM ENGINEERING.

CHARLES E. DRESSEL
BOOK SELLER
552 BROAD ST.,
NEWARK, N. J.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1879.

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NAVAL ACADEMY,
Annapolis, Md., October 25, 1879.

SIR: In obedience to the orders of the Bureau of Steam Engineering "to make a series of experiments to determine the value and resistance of screw stay-bolts for boilers under different conditions, using iron, steel, and copper plates of different thicknesses," &c., we respectfully state that we have complied as fully as possible during the time occupied, and that every care and precaution was used to insure accuracy; that in every experiment where there was the least doubt it was set aside and another trial made. Want of time prevents the discussion of the matter as fully as desirable; but we beg leave to submit the inclosed plates, data, &c., with a short *resumé* of the work, results, and those points brought most prominently into notice during the tests. In connection with and illustrating these experiments the following tables and sketches are respectfully submitted:

Tables A, A^1, A^2, showing comparative resistance of iron screw stay-bolts, under different conditions, to being pulled through iron boiler-plate.

Table A^3. Results (for comparison) of pulling iron screw stay-bolts through "low" steel boiler-plate.

Tables B, B^1. Results (for comparisons) of pulling copper screw stay-bolts through iron boiler-plates.

Tables C, C^1. Results (for comparisons) of pulling iron screw stay-bolts through copper boiler-plates.

Table D. Results (for comparisons) of pulling copper screw stay-bolts through copper boiler-plates.

Plate X shows the arrangement of the bolts for the above tests for comparisons.

Plates 1 to 45, showing data and sketch (after rupture) of the different experiments on iron and low steel stay-bolts, and iron, low steel, and copper boiler-plates, arranged so as to represent a section of a fire-box.

Tests to determine the comparative force necessary to pull screw stay-bolts of iron and copper through iron, low steel, and copper boiler-plates.

1. All plates of each material, of the same thickness, were cut from the same sheet.

2. All stay-bolts of each material were made from the same bar, or from bars of the same lot, which, after testing, were found to be as nearly similar as possible in all respects.

3. Three specimens of each size and thickness were tested.

4. All tests were carefully observed until rupture. Three trials each were first made with ½″ iron plates and 1″ iron stay-bolts, not riveted, and riveted over with the ordinary thin or low conical head, simply arranged so as to show the actual strength, to resist pulling through the plate, the supports consisting of heavy plates, with a hole 1¾″ in diameter; the boiler plate resting upon the heavy plate and the stay-bolt adjusted to the center of the hole; thus allowing the bolt to have a clear space around it equal to the overlapping of the riveted head on the boiler plate. The bolts not riveted drew out at an average strain of 32,785 pounds; those riveted with

the low conical head made according to general practice, by leaving thin threads through to form the head, required an average strain of 35,033 pounds to draw them through the plate; the rivet-head giving an additional strength of 2,248 pounds in a 1″ stay-bolt.

In testing those with low conical heads, it was observed that the bulging of the plates caused the lap of the rivet-head on the plate to commence giving way or break off some time before the maximum strain was reached, thus leaving more for the threads on the bolts to sustain. As the strain and bulge of the plates increased, the plate around the bolt turned downward and outward until the threads in the plate almost entirely cleared those on the bolts, so that in almost every case there were only from one to two threads stripped or injured on the bolt when it drew out; therefore it was deemed advisable to form the head in a different manner, and, after several experiments, it was decided that the rivet-head should be made as follows: First, by leaving as much of the bolt through the plate as could be riveted over without injury to the iron, which was, in case of the excellent iron being used, equal in length to about one-half the diameter of the bolt. This was riveted over in the following manner: A few quick, sharp blows were struck on the end, slightly upsetting the iron; the head was then formed to shape with a button-head set made to a spherical segment.

It was found that this could be done in nearly the same time as that used in riveting the ordinary low conical stay-bolt heads at the Washington yard, and with much less injury to the iron; also, that it only required one riveter and a helper; whereas, by the old method, two riveters were used.

Three trials each were then made with ½″ iron plates and 1″ iron stay-bolts (arranged as shown in Plate X), not riveted; riveted with ordinary low conical head, with 3 threads left through for riveting; riveted with button-head, a little over 5 threads left through for riveting; and with button-head, the size of stay-bolt being increased to 1¼″. The supports were by bolts in each corner of the plate, 4″ and 5″ from center to center of supports; the stay-bolt being in the center of the plate, equally distant from each support.

The ultimate average strain required to pull the above bolts through the ½″ plate was as follows:

With supports 4″ from center to center.

	Pounds.
1″ bolt, not riveted	21,970
1″ bolt, *ordinary low conical head*, 3 threads left through for riveting	25,147
1″ bolt, *button-head;* length of bolt left through for riveting equal to $\frac{7}{16}$ diameter of bolt	33,791
1¼″ bolt, *button-head;* length left through for riveting equal to ½ diameter of bolt	38,885

With supports 5″ from center to center.

1″ bolt, *ordinary low conical head*	22,137
1″ bolt, *button-head;* length left through for riveting equal to $\frac{7}{16}$ diameter of bolt	31,282
1¼″ bolt, *button-head;* length left through for riveting equal to ½ diameter of bolt	35,812

The above shows what important factors the rivet-head, and manner in which it is formed, as well as the size of the bolt, are to screw stay-bolts for surfaces resisting internal pressure.

Experiments on screw stay-bolts and plates, arranged to represent a section of a fire-box, water being used to produce the strain.

These drawings show the apparatus as used in each experiment. It consists of a composition ring 4 inches deep, 18 inches internal and 23 inches external diameter, faced true on both sides, and having thirty-one holes for ⅞-inch through bolts; and on each side of the connecting-pipe to the pump a hole was tapped for a bolt of the same diameter. These holes were laid off and drilled equidistant on a circle 20½ inches in diameter.

The bolts for securing the plates to the ring were of steel, turned and chased to fit ⅞-inch hexagonal nuts. The joints between the plates and ring were made with a sheet-lead gasket coated with soft red-lead putty.

After a few experiments with stay-bolts, riveted at both ends, and plates of equal thickness on both sides of the ring (for economizing the number of plates used), a ¾-inch steel plate, having holes that allowed the stay-bolt to pass freely through them, was used for a back-plate, as is shown in the drawings of most of the experiments.

The stay-bolts where they passed through the back plate were packed under the washer with lamp-wick and red-lead putty, and the nuts were screwed up firmly before the riveted head was made on the other end of the bolt.

All the experimental plates were cut to the diameter of the outside of the composition ring, made flat, and the holes drilled accurately.

The iron plates were selected from a lot made and delivered by the manufacturers at the same time. Those of the same thickness were cut where possible from the same sheet.

The Otis steel plates were received of the right size and shape from the manufacturers.

The copper plates were rolled per order from one quality of material at the navy-yard, Washington.

The iron stay-bolts were made from 1⅛-inch and 1¼-inch round bars that had stood bending through 180 degrees cold without showing signs of fracture, and of a tensile strength ranging from 51,000 to 52,000 pounds per square inch.

The Otis steel stay-bolts were made from bars of that material that were of the diameter required for the bolts. The tensile strength per square inch of the 1-inch bar was 58,869 pounds, and of the 1⅛-inch bar 52,825 pounds.

The threads on the stay-bolts were cut to screw tightly through the holes tapped in the plates, and the exact number stated in the data were left projecting to form the heads. The riveting was done with great care; the low conical or ordinary heads were made and finished with hammers in the usual manner. The upsetting for the segmental heads was done with hammers, and the shaping and finishing with the button-head set.

Where *nuts* were used in the place of riveted heads, the stay-bolts were screwed through the plate and the nuts set up tightly against it. The nuts were faced on their bearing side and then dished out $\frac{1}{16}$ of an inch deep, leaving a bearing surface in the form of a ring around the outside. The dished space was filled with red-lead putty made stiff with fine iron borings. *The measurements* for the bulge of the plate were taken while the pressure was on the apparatus, and those for the set were taken after it had been relieved.

Both measurements were from points (between the stay-bolts) found to be the highest, and in no case were they taken from less than four places in each plate.

The figures on the stay-bolts, where found in the drawings, show the elongation of the bolt in inches during the test.

The pressure-gauges were frequently tested to insure accuracy.

Forty-five (45) experiments were made with iron and steel stay-bolts and iron, steel, and copper boiler-plate, arranged to represent a section of a fire-box.

The steel plates and bolts were made from a low steel, manufactured by the Otis Steel Company, of Cleveland, Ohio. The stay-bolts possessed a remarkable malleability, requiring comparatively very little hammering to form the rivet-head. In comparing the results of three different thicknesses, in each case (¼", ⅜", ½" plate) of iron plates and iron bolts, steel plates and iron bolts, steel plates and steel bolts, the diameter of the bolts being 1", 1⅛", and 1¼", their distance apart and conditions of trial being the same, it was found that in the case of the iron plates and iron bolts the strain required to draw the bolts through the plates was equal to 74.77 per cent. of the tensile strength of the bolt, with the steel plates and iron bolts 77.36 per cent., and with the steel plate and steel bolts 85.42 per cent.

The following is a comparison of results in regard to the best methods of forming or securing the heads of screw stay-bolts for steam-boilers, the thickness of the plates (½") and the distance apart of the bolts (5") being the same in each case; the amounts given are in pounds per square inch of surface supported:

1" bolt, ordinary low conical head (see Plate 2*a*)	580 pounds.
1" bolt, button-head (spherical segment) (see Plate 3*b*)	790 pounds.

Difference in favor of button-head, 210 pounds, or 36.2 per cent.

Below is a similar comparison with ⅜" plates and bolts 6" from center to center:

1" bolt, ordinary low conical head (see Plate 8*f*)	650 pounds.
1" bolt, button-head (spherical segment) (Plate 9*g*)	800 pounds.

Difference in favor of button-head, 150 pounds, or 23 per cent.

As a means of comparison for strength only, the following experiments (thickness of plates and distances apart of bolts same as above) were made with nuts instead of riveted heads, the nuts being of the standard size for the diameter of bolt used and fitted in accordance with the data on the sketches and note in the general explanation in regard to the experiments:

	Pounds.
1" bolt, 4" from center to center, bearing surface a little more than rivet (see Plate 33*c*)	1,000
1" bolt, 6" from center to center, bearing surface a little more than rivet (see Plate 36*h*)	1,300
1" bolt, 5" from center to center, bearing surface double that of above rivet (see Plate 34*d*)	1,500
1¼" bolt, 5" from center to center, bearing surface double that of above rivet (see Plate 35*e*)	1,650

By comparing the above, it will be seen that there was a gain of from 23 to 36.2 per cent. in favor of the button-head over the ordinary low conical head. Also the percentage in ***strength*** over all was largely in favor of the nuts, which would be of value in surfaces not exposed to the action of extreme heat and flame, experience having shown that the difficulties in preventing leakage around the thread and the burning away of the nuts materially affects their durability and efficiency.

Want of time prevents the discussion of all the experiments in regard to the resistance of screw stay-bolts in flat surfaces. But in reference to iron and low steel bolts, and iron and low steel plates, and copper plates and iron bolts, after a careful examination of the results of these experiments in particular, we are satisfied that the following formulæ will correctly and safely represent the working strength of good material in flat surfaces, supported by screw stay-bolts with riveted button-shaped heads or with nuts, when the thickness of the plates forming said surfaces and the screw stay-bolts are made in accordance with the dimensions and conditions given in table Y. W= safe-working pressure; T= thickness of plate; d= distance from center to center of stay-bolt:

For iron plates and iron bolts .... $W = 24000 \frac{T^2}{d^2}$

For low steel plates and iron bolts .... $W = 25000 \frac{T^2}{d^2}$

For low steel plates and low steel bolts .... $W = 28000 \frac{T^2}{d^2}$.

For iron plates and iron bolts, with nuts .... $W = 40000 \frac{T^2}{d^2}$

For copper plates and iron bolts .... $W = 14500 \frac{T^2}{d^2}$

To obtain the ultimate bursting pressure, multiply the results of the above formulæ by 8, which is the factor of safety used.

TABLE Y.—*Dimensions and conditions for making iron and low steel screw stay-bolts for flat surfaces subject to internal pressure for distances ranging from four to eight inches (inclusive) from center to center of stay-bolt.*

Thickness of plate.	Diameter of bolt outside of thread.	Number of threads per inch.	Length of bolt left through for riveting in fractions of diam of bolt.	Height of rivet-head when finished.	Diameter of base of rivet-head not to exceed when finished—	Nuts.	
						Breadth of annular bearing surface.	Dished out to a depth of—
1/4″	1 ″	14	[illegible]	7/16″	1 5/16″	1/16″	1/16″
3/8″	1 1/8″	14	[illegible]	1/2″	1 9/16″	1/8″	1/16″
1/2″	1 1/4″	12	[illegible]	9/16″	1 3/4″	3/16″	3/32″
5/8″	1 3/8″	12	[illegible]	5/8″	1 7/8″	1/4″	3/32″

The rivet-heads to be a segment of a sphere, formed by first upsetting the end of the bolt with a few quick, sharp blows of the hammer, then finished to shape with the hammer and button-head set. Where nuts *can* be used instead of riveted heads, they should be of the standard size, suited to the diameter of the bolt, faced on the side bearing on the plate, and dished out so as to form an annular bearing surface of as large a diameter as the nut will allow, and of a breadth and depth given in the table. Before securing the nut in place the dished portion should be filled with red-lead putty made stiff with *fine* iron borings.

Respectfully submitted.

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TABLE A.

Experiments with screw stay-bolts, with ends not riveted, riveted over with the ordinary low conical head, riveted over with a button-head set, and with stay-bolts of an increased size, riveted over with button-head set. Also two experiments to show the force necessary, simply, to draw the bolt through the plate, both when not riveted and when riveted with low conical head. Tensile strength of bar for bolts 54,498 *pounds per square inch. The arrangement of plates and stay-bolts is shown in Plate X.*

Number and mark of specimens.	Thickness of boiler plate.	Diameter of stay-bolt outside of thread.	Diameter of stay-bolt inside of thread.	Distance from center to center of supporting bolts.	Number of threads left through for riveting.	Mean diameter of head after riveting.	Number of threads on bolts to the inch.	Thickness of rivet-head at crown.	Plate commenced to bulge at—	Kind of rivet-head.	Bolt or plate gave way at—	Total bulge of plate after rupture.	Remarks.
	Inches.	*Inches.*	*Inches.*	*Inches.*		*Inches.*		*Inches.*	*Lbs.*		*Lbs.*	*Inches.*	
1..........	.5	1.017	.920	Support was a hole $1\frac{3}{4}''$ diameter in a heavy plate.	......	Not riveted.	12	....	....	Threads only projecting.	36,095	Not perceptible	Bolts pulled through, stripping threads in plate and bolt.
11........	.5	1.017	.920		......	..do ...	12	....	....	....do	33,860	..do ...	This plate was supported the same as that below, with a plate (heavy) with $1\frac{3}{4}''$ hole.
111.......	.5	1.017	.920		......	..do ...	12	....	....	....do	28,400	..do ...	
Average	.5	1.017	.920	....	......	....	12	....	....	....	32,785	....	
1..........	.5	1.020	.9	Same as above.	3—	$1\frac{7}{16}$	12	$\frac{7}{32}$	....	Ordinary thin conical head.	34,770	Not perceptible	Stay-bolts broke between plates; they were riveted with thin head in the usual manner.
11........	.5	1.020	.9		3—	$1\frac{7}{16}$	12	$\frac{7}{32}$	....	....do	30,340	..do ...	The plate was supported by a heavy plate, in which was a hole $1\frac{3}{4}''$ in diam., the stay-bolt passing through the hole to its place of attachment.
111.......	.5	1.020	.9		3—	$1\frac{7}{16}$	12	$\frac{7}{32}$	....	....do	34,990	..do ...	Head of rivet was apparently uninjured.
Average	.5	1.020	.9	....	3	$1\frac{7}{16}$	12	$\frac{7}{32}$	....	....	35,033	....	
1..........	.498	1.015	.919	4	....	Not riveted.	12	....	12,700	Thread only projecting.	22,650	$\frac{5}{16}$	Bolts pulled through, stripping threads on bolt, and one-half of them in the plate.
11........	.498	1.015	.919	4	....	..do ...	12	....	14,000	....do	21,720	$\frac{9}{32}$	
111.......	.498	1.015	.919	4	....	..do ...	12	....	14,000	....do	21,600	$\frac{5}{16}$	
Average	.498	1.015	.919	4	....	....	12	....	13,566	....	21,970	$\frac{29}{96}$	
1..........	.5	1.020	.9	4	3—	$1\frac{3}{8}$	12	$\frac{7}{32}$	....	Ordinary thin conical head.	24,510	.39	1 and $1\frac{1}{2}$ threads injured; the bulge of the plate allowed the other threads of the bolt and the plate to clear each other, so as to leave them uninjured.
11........	.5	1.020	.9	4	3—	$1\frac{3}{8}$	12	$\frac{7}{32}$	....	....do	24,830	.33	

1 1 1	.5	1.020	.9	4	3–	1½	12	7/32	....	....do	26,100	.40	
Average.	.5	1.020	.9	4	3	1.418	12	7/32	....	....	25,147	.373	
1...........	.504	1.016	.920	4	5+	1¼	12	7/16	12,600	Button-head...	32,775	9/16	Head stripped and bolt pulled through; threads left good in plate; slight crack around hole.
1 1.........	.504	1.016	.920	4	5+	1¼	12	3/8	13,000	....do	33,000	5/8	Head and end of bolt torn off; all threads in plate injured; cracks in hole 3/8" long.
1 1 1	.504	1.016	.920	4	5+	1¼	12	7/16	11,000	....do	35,600	11/16	Head and part of thread on bolt stripped; thread in plate but slightly injured.
Average.	.504	1.016	.920	4	5+	1.25	12	.4166	12,200	....	33,791.8	.625	
....	.5	1.245	1.145	4	5+	1 9/16	12	1/2	19,650	Button-head...	38,960	3/4	Bolts pulled through; heads partly stripped; 2 threads left good in holes; cracks on opposite sides of holes 1/8" to 3/4" long.
....	.498	1.245	1.145	4	5+	1 9/16	12	15/32	18,575	....do	35,900	19/32	
....	.498	1.245	1.147	4	5+	1 17/32	12.	15/32	17,750	....do	41,795	21/32	
Average.	.4986	1.245	1.1456	4	5+	1.55238	12	.47916	18,658.6	....	38,885	.6666	
1 1 1	.503	1.020	.9	5	3 scant.	1 7/16	12	7/32	....	Ordinary thin conical head.	23,125	.5	2 threads stripped; all the rest uninjured, the bulge of plate allowing them to clear each other.
1 1 1 1......	.503	1.020	.9	5	3 scant.	1 7/16	12	7/32	....	....do	21,310	.49	
1 1 1 1 1....	.503	1.020	.9	5	3 scant.	1 7/16	12	7/32	....	....do	21,975	.42	
Average.	.503	1.020	.9	5	3	1 7/16	12	7/32	....	....	22,137	.47	
1...........	.506	1.017	.9015	5	5+	17/32	12	13/32	13,000	Button-head...	31,450	21/32	Heads stripped, bolts pulled out; 3 good threads left in hole; cracked back nearly 1/8" on opposite sides of holes.
1 1.........	.509	1.017	.9015	5	5+	17/32	12	14/32	12,500	....do	31,500	21/32	
1 1 1	.512	1.017	.9015	5	5+	17/32	12	15/32	12,085	....do	30,895	23/32	Small crack all around the hole 1/8" to 1/8" long.
Average.	.509	1.017	.9015	5	5+	17/32	12	7/16	12,528	....	31,282	.67708	
....	.5	1.242	1.159	5	5+	1½	12	15/16	12,900	Button-head...	35,450	29/32	Bolts pulled through; heads on bolts stripped; threads on bolts and in holes but slightly injured; small cracks around holes in the plate.
....	.498	1.245	1.160	5	5+	1 17/32	12	15/16	10,466	....do	36,935	7/8	
....	.498	1.255	1.156	5	5+	1 17/32	12	15/16	11,500	....do	35,050	3/4	
Average.	.4986	1.2473	1.1583	5	5+	1.5208	12	.9375	11,622	....	35,812	.84375	

In the specimens riveted over with the ordinary low conical head, three threads projecting through for this purpose, in the manner heretofore practiced at this yard, it was observed that the edges of the head overlapping the plate gave way some time before the bolt drew out. In order to obviate this the button-head was successfully tried, with a length left through for riveting equal to about seven-sixteenths the diameter of the bolt.

TABLE A 1.

Iron plates and iron screw stay-bolts from No. 5 bar. Tensile strength of stays 56,683 pounds per square inch.

Number and marks on specimens.	Thickness of boiler-plate.	Diameter of stay-bolt outside of thread.	Diameter of stay-bolt inside of thread.	Distance from center to center of supporting bolts.	Number of threads left for riveting.	Mean diameter of head after riveting.	Number of threads on bolt to the inch.	Thickness of rivet-head at the crown.	Plate commenced to bulge at—	Bulge of plate at double the strain at which commenced.	Bolt or plate gave way at—	Total bulge of plate after rupture.	Remarks.
	Inches.	*Inches.*	*Inches.*	*Inches.*		*Inches.*		*Inches.*	*Lbs.*	*Inches.*	*Lbs.*	*Inches.*	
1.....	$\frac{1}{4}$ .250	.815	.750	4	5	$1\frac{1}{8}$	14	$\frac{11}{32}$	4,150	$\frac{3}{8}$	11,575	$\frac{5}{8}$	Bolts pulled out, stripping head; two good threads left in holes; cracks on opposite side of hole $\frac{3}{8}$″ long.
11...	$\frac{1}{4}$ .250	.815	.750	4	5	$1\frac{1}{8}$	14	$\frac{11}{32}$	4,500	$\frac{3}{8}$	10,950	$\frac{19}{32}$	
111..	$\frac{1}{4}$ .250	.815	.750	4	5	$1\frac{1}{8}$	14	$\frac{21}{64}$	4,100	$\frac{9}{32}$	11,550	$\frac{17}{32}$	
1.....	$\frac{3}{8}$ .360	.870	.768	4	5	$1\frac{1}{8}$	12	$\frac{13}{32}$	5,850	$\frac{3}{32}$	18,830	$\frac{21}{32}$	Bolts pulled through; three good threads left in holes; cracked back on two sides of hole $\frac{3}{8}$″; rivet-head stripped.
11...	$\frac{3}{8}$ .370	.870	.768	4	5	$1\frac{1}{8}$	12	$\frac{13}{32}$	5,150	$\frac{1}{16}$	18,810	$\frac{9}{16}$	
111..	$\frac{3}{8}$ .368	.870	.768	4	5	$1\frac{1}{8}$	12	$\frac{13}{32}$	6,000	$\frac{5}{32}$	19,575	$\frac{19}{32}$	
1.....	$\frac{1}{2}$ .498	1.010	.912	4	5	$1\frac{7}{32}$	12	$\frac{15}{32}$	15,000	$\frac{7}{16}$	36,000	$\frac{7}{16}$	Head stripped; bolt pulled through; slight cracks in hole; threads left good in plate.
11...	$\frac{1}{2}$ .498	1.010	.912	4	5	$1\frac{7}{32}$	12	$\frac{7}{16}$	13,250	$\frac{3}{16}$	36,250	$\frac{1}{2}$	Head and end of bolt torn off; all threads in hole injured; cracks around hole $\frac{3}{8}$″ back.
111..	$\frac{1}{2}$ .500	1.010	.912	4	5	$1\frac{7}{32}$	12	$\frac{15}{32}$	15,000	$\frac{7}{16}$	34,075	$\frac{17}{32}$	Head and part of threads on bolt stripped; threads in hole slightly injured; cracked around hole.
1.....	$\frac{1}{4}$ .254	.818	.745	5	5	$1\frac{1}{8}$	14	$\frac{23}{64}$	2,370	$\frac{9}{64}$	11,910	$\frac{25}{32}$	Bolts pulled out; two good threads left in hole; cracks on side of hole from $\frac{3}{8}$″ to $\frac{7}{8}$″ long.
11...	$\frac{1}{4}$ .254	.818	.745	5	5	$1\frac{1}{8}$	14	$\frac{5}{16}$	2,750	$\frac{1}{8}$	12,525	$\frac{3}{4}$	
111..	$\frac{1}{4}$ .254	.818	.745	5	5	$1\frac{1}{8}$	14	$\frac{11}{32}$	3,000	$\frac{3}{16}$	12,910	$\frac{13}{16}$	

1.....	$\frac{3}{8}$ .372	.870	.768	5	5	$1\frac{1}{8}$	12	$\frac{13}{32}$	5, 450	$\frac{1}{8}$	15, 940	$\frac{21}{32}$	Heads stripped and bolts pulled out; three good threads left in hole; cracked back nearly 1″ on opposite side of holes.
11...	$\frac{3}{8}$ .372	.870	.768	5	5	$1\frac{1}{8}$	12	$\frac{13}{32}$	4, 850	$\frac{1}{8}$	17, 100	$\frac{11}{16}$	
111..	$\frac{3}{8}$ .371	.870	.768	5	5	$1\frac{1}{8}$	12	$\frac{25}{64}$	4, 725	$\frac{3}{32}$	17, 730	$\frac{11}{16}$	
1.....	$\frac{1}{2}$ .495	1	.912	5	5	$1\frac{1}{4}$	12	$\frac{31}{64}$	11, 000	$\frac{3}{16}$	33, 860	$\frac{13}{16}$	Head stripped; bolts pulled out; 3 good threads left in hole; cracks on each side of hole $\frac{7}{8}$″ long.
11...	$\frac{1}{2}$ .495	.998	.912	5	5	$1\frac{7}{32}$	12	$\frac{15}{32}$	9, 550	$\frac{3}{16}$	32, 210	$\frac{3}{4}$	Head stripped; bolts pulled out; 3 good threads left in hole; cracks all around hole $\frac{1}{8}$″ to $\frac{3}{4}$″ long.
111..	$\frac{1}{2}$ .495	.998	.912	5	5	$1\frac{7}{32}$	12	$\frac{7}{16}$	13, 400	$\frac{7}{32}$	33, 675	$\frac{3}{4}$	

All stay-bolts in this table were screwed and riveted over heads formed with button-head set.

TABLE A 2.

Iron plates and iron screw stay-bolts from bar No. —. Tensile strength, 56,683 *pounds, with increased size of stay-bolts.*

Number and marks on specimens.	Thickness of boiler-plate.	Diameter of stay-bolt outside of thread.	Diameter of stay-bolt inside of thread.	Distance from center to center of supporting bolts.	Number of threads left for riveting.	Mean diameter of head after riveting.	Number of threads on bolt to the inch.	Thickness of rivet-head at the crown.	Plate commenced to bulge at—	Bulge of plate at double the strain at which commenced.	Bolt or plate gave way at—	Total bulge of plate after rupture.	Remarks.
	Inches.	*Inches.*	*Inches.*	*Inches.*		*Inches.*		*Inches.*	*Lbs.*	*Inches.*	*Lbs.*	*Inches.*	
1.....	$\frac{1}{4}$ .250	1.004	.945	4	5	$1\frac{3}{16}$	14	$\frac{13}{32}$	3,600	$\frac{7}{32}$	13,940	$\frac{11}{16}$	Bolts pulled through; heads partly stripped; all threads in hole slightly injured; small cracks around hole.
11...	$\frac{1}{4}$ .247	1.004	.942	4	5	$1\frac{7}{32}$	14	$\frac{3}{8}$	3,000	$\frac{5}{32}$	13,460	$\frac{21}{32}$	
111..	$\frac{1}{4}$ .245	1.004	.940	4	5	$1\frac{1}{4}$	14	$\frac{3}{8}$	3,250	$\frac{3}{16}$	12,675	$\frac{21}{32}$	
1.....	$\frac{3}{8}$ .368	1.150	1.056	4	5	$1\frac{1}{2}$	12	$\frac{7}{16}$	9,500	$\frac{3}{16}$	21,420	$\frac{21}{32}$	Bolts pulled through; heads partly stripped; threads left good in hole; cracks on opposite sides of holes from $\frac{7}{8}$″ to $1\frac{1}{2}$″ long.
11...	$\frac{3}{8}$ .374	1.150	1.057	4	5	$1\frac{1}{2}$	12	$\frac{7}{16}$	12,000	(*)	20,950	$\frac{21}{32}$	
111..	$\frac{3}{8}$ .377	1.150	1.057	4	5	$1\frac{1}{2}$	12	$\frac{7}{16}$	11,550	$\frac{1}{4}$	23,475	$\frac{9}{16}$	
1.....	$\frac{1}{2}$ .500	1.245	1.145	4	5	$1\frac{9}{16}$	12	$\frac{1}{2}$	16,960	$\frac{17}{32}$	38,960	$\frac{3}{4}$	Bolts pulled through; heads partly stripped; threads left good in hole; threads on bolt but little injured; small cracks around hole, $\frac{1}{8}$″ to $\frac{3}{4}$″ long.
11...	$\frac{1}{2}$ .498	1.245	1.145	4	5	$1\frac{9}{16}$	12	$\frac{15}{32}$	18,575	(*)	35,900	$\frac{19}{32}$	
111..	$\frac{1}{2}$ .498	1.245	1.147	4	5	$1\frac{17}{32}$	12	$\frac{15}{32}$	17,750	$\frac{41}{64}$	41,795	$\frac{21}{32}$	
1.....	$\frac{1}{4}$ .253	1.003	.945	5	5	$1\frac{7}{32}$	14	$\frac{11}{32}$	2,500	$\frac{7}{32}$	12,850	$\frac{7}{8}$	Bolts pulled through; heads partly stripped; two threads left good in holes; cracks on opposite sides of hole $\frac{1}{8}$″ to $\frac{5}{8}$″ long.
11...	$\frac{1}{4}$ .253	1.003	.941	5	5	$1\frac{7}{32}$	14	$\frac{13}{32}$	2,375	$\frac{5}{32}$	12,800	$\frac{7}{8}$	
111..	$\frac{1}{4}$ .250	1.004	.939	5	5	$1\frac{7}{32}$	14	$\frac{13}{32}$	2,350	$\frac{5}{32}$	11,940	$\frac{27}{32}$	

1.....	3/8 .371	1.157	1.060	5	5	1½	12	15/32	8,625	⅛	19,700	¾	Bolts pulled through; heads partly stripped; threads on bolts and in holes but slightly injured; cracks on opposite sides of holes from 1⅛″ to 1⅞″ long.
11...	3/8 .369	1.160	1.056	5	5	1½	12	7/16	9,010	9/16	20,750	13/16	
111..	3/8 .374	1.155	1.050	5	5	1½	12	13/32	7,650	⅜	19,875	¾	
1.....	½ .500	1.242	1.159	5	5	1⅛	12	15/16	12,900	7/16	35,450	29/32	Bolts pulled through; heads on bolts stripped; threads on bolts and in holes but slightly injured; small cracks around holes.
11...	½ .498	1.245	1.160	5	5	1 17/32	12	15/16	10,466	¼	36,935	⅞	
111..	½ .498	1.255	1.156	5	5	1 17/32	12	15/16	11,500	5/32	35,050	¾	

(*) Strain not reached.

All stay-bolts in this table were screwed and riveted on; heads formed with a button-head set.

TABLE A 3.

Iron plates and iron screw stay-bolts from plate No. 1 *bar. Tensile strength,* 54,498 *pounds per square inch.*

Number and mark on specimen.	Thickness of boiler-plate.	Diameter of stay-bolt outside of thread.	Diameter of stay-bolt inside of thread.	Distance from center to center of supporting bolts.	Number of threads left for riveting.	Mean diameter of head after riveting.	Number of threads on bolt to the inch.	Thickness of rivet-head at crown.	Plate commenced to bulge at—	Bolt or plate gave way at—	Total bulge of plate after rupture.	Remarks.
	Inches.	*Inches.*	*Inches.*	*Inches.*		*Inches.*		*Inches.*	*Lbs.*	*Lbs.*	*Inches.*	
1.......	.201	.829	.738	5	5	$1\frac{3}{32}$	14	$\frac{11}{32}$	....	8, 970	$\frac{11}{16}$	Bolt pulled through plate. The bulging of the plate left two threads uninjured. No cracks in plate.
1 1	.201	.829	.738	5	5	$1\frac{3}{32}$	14	$\frac{11}{32}$	....	13, 425	$\frac{3}{4}$	
1 1 1 ...	.201	.829	.738	5	5	$1\frac{1}{16}$	14	$\frac{19}{32}$	....	9, 950	$\frac{5}{8}$	
1.......	.277	.872	.770	5	5	$1\frac{1}{8}$	12	$\frac{11}{32}$	....	14, 830	$\frac{3}{4}$	Do.
1 1	.278	.872	.770	5	5	$1\frac{1}{8}$	12	$\frac{19}{32}$	....	11, 950	$\frac{9}{16}$	
1 1 1 ...	.276	.872	.770	5	5	$1\frac{1}{8}$	12	$\frac{11}{32}$	....	15, 630	$\frac{3}{4}$	
1.......	.3115	1.020	.917	5	5	$1\frac{3}{16}$	12	$\frac{3}{8}$	....	18, 950	$\frac{3}{4}$	Bolt pulled through plate. Same as above, except that three threads were left uninjured.
1 1	.3115	1.020	.917	5	5	$1\frac{7}{32}$	12	$\frac{11}{32}$	....	18, 050	$\frac{13}{16}$	
1 1 1 ...	.3110	1.020	.917	5	5	$1\frac{7}{32}$	12	$\frac{3}{8}$	....	18, 000	$\frac{3}{4}$	
1.......	.195	.828	.737	4	5	$1\frac{1}{8}$	14	$\frac{23}{64}$	3, 600	10, 630	$\frac{1}{2}$	Bolt pulled through plate. Same as above, except two threads left uninjured.
1 1	.202	.828	.737	4	5	$1\frac{3}{32}$	14	$\frac{11}{32}$	3, 500	11, 350	$\frac{33}{64}$	
1 1 1 ...	.195	.828	.737	4	5	$1\frac{3}{32}$	14	$\frac{11}{32}$	....	11, 610	$\frac{1}{2}$	
1.......	.25											Were unable to find in the yard any more ¼" steel plates of the same quality as the other.
1 1	.25	....	....	....	....	....	....	....	....	....	....	
1 1 1 ...	.25											
1.......	.303	1.015	.919	4	5	$1\frac{1}{4}$	12	$\frac{15}{32}$	8, 000	22, 300	$\frac{13}{32}$	Bolt pulled through plate. The bulging of the plates left two threads uninjured.
1 1	.3038	1.015	.919	4	5	$1\frac{1}{4}$	12	$\frac{14}{32}$	8, 500	21, 960	$\frac{21}{32}$	
1 1 1 ..	.304	1.015	.919	4	5	$1\frac{7}{32}$	12	$\frac{1}{2}$	8, 600	20, 790	$\frac{13}{32}$	

All of stay-bolts in this table were screwed and riveted over; the head being formed with a button-head set.

TABLE B.

Iron boiler plate and copper screw stay-bolts.

Number and mark on specimen.	Thickness of boiler-plate.	Diameter of stay-bolt outside of thread.	Diameter of stay-bolt inside of thread.	Distance from center to center of supporting bolts.	Number of threads left for riveting.	Mean diameter of head after riveting.	Number of threads on bolt to the inch.	Thickness of rivet-head at crown.	Plate commenced to bulge at—	Bolt or plate gave way at—	Total bulge of plate after rupture.	Remarks.
	Inches.	*Inches.*	*Inches.*	*Inches.*		*Inches.*		*Inches.*	*Lbs.*	*Lbs.*	*Inches.*	
1.......	.280	.816	.736	4	6	$1\frac{3}{32}$	14	$\frac{3}{8}$	6, 450	11, 950	$\frac{17}{32}$	Bolts pulled through; all the threads somewhat injured; plates cracked in two places on opposite sides of the hole.
1 1.....	.288	.816	.738	4	6	$1\frac{1}{8}$	14	$\frac{25}{64}$	6, 000	12, 580	$\frac{5}{8}$	
1 1 1....	.288	.816	.736	4	6	$1\frac{1}{8}$	14	$\frac{13}{32}$	6, 000	12, 680	$\frac{5}{8}$	
1.......	.382	.822	.738	4	6	$1\frac{3}{32}$	14	$\frac{6}{16}$	8, 000	16, 640	$\frac{3}{8}$	Bolts pulled through; rivet head pulled off in shape of a ring; where it lapped over the plate slight cracks around holes; two to three threads injured in plate. On No. 1 1 1 bolt, all threads were stripped and all but three in the plate.
1 1.....	.384	.821	.736	4	6	$1\frac{1}{8}$	14	$\frac{11}{32}$	9, 000	17, 930	$\frac{25}{64}$	
1 1 1....	.382	.822	.736	4	6	$1\frac{1}{8}$	14	$\frac{5}{16}$	10, 000	16, 870	$\frac{27}{64}$	
1.......	.479	.859	.766	4	6	$1\frac{1}{8}$	12	$\frac{3}{8}$	14, 000	22, 595	$\frac{21}{64}$	Bolt broke; ends left loose in hole; rivet head but little injured.
1 1.....	.479	.859	.766	4	6	$1\frac{9}{64}$	12	$\frac{3}{8}$	14, 000	22, 390	$\frac{5}{16}$	Bolt pulled out, leaving head and threads stripped; one thread in plate uninjured.
1 1 1....	.480	.859	.766	4	6	$1\frac{1}{8}$	12	$\frac{3}{8}$	14, 500	22, 795	$\frac{5}{16}$	
1.......	.505	1. 012	.908	4	6	$1\frac{1}{4}$	12	$\frac{19}{64}$	15, 000	28, 380	$\frac{1}{2}$	Bolt pulled out, stripping head and threads; only one thread in plate uninjured.
1 1.....	.510	1. 012	.908	4	6	$1\frac{1}{4}$	12	$\frac{22}{64}$	15, 600	28, 435	$\frac{3}{8}$	Bolts pulled out, stripping head and threads; threads in plate but little injured.
1 1 1....	.510	1. 012	.908	4	6	$1\frac{1}{4}$	12	$\frac{23}{64}$	16, 700	28, 560	$\frac{21}{64}$	Bolt broke leaving ends tight in plate.

All stay-bolts in this table were screwed and riveted over; the heads being formed with a button-head set.

TABLE B1.

Iron boiler-plates and copper screw stay-bolts.

Number and marks on specimens.	Thickness of boiler-plate.	Diameter of stay-bolt outside of thread.	Diameter of stay-bolt inside of thread.	Distance from center to center of supporting bolts.	Number of threads left for riveting.	Mean diameter of head after riveting.	Number of threads on bolt to the inch.	Thickness of rivet-head at the crown.	Plate commenced to bulge at—	Bulge of plate at double the strain at which commenced.	Bolt or plate gave away at—	Total bulge of plate after rupture.	Remarks.
	Inches.	*Inches.*	*Inches.*	*Inches.*		*Inches.*		*Inches.*	*Lbs.*	*Inches.*	*Lbs.*	*Inches.*	
1.....	$\frac{1}{4}$ .248	.820	.747	4	5	$\frac{1}{8}$	14	$\frac{11}{32}$	3,800	$\frac{1}{4}$	11,850	$\frac{17}{32}$	Heads stripped; bolt pulled out; 2 good threads left in plate; crack $\frac{1}{2}$″ on one side of hole.
11...	$\frac{1}{4}$ .248	.820	.747	4	5	$\frac{1}{8}$	14	$\frac{11}{32}$	4,000	$\frac{9}{32}$	11,610	$\frac{17}{32}$	Same as above, except crack $\frac{1}{4}$″ on each side of hole.
111..	$\frac{1}{4}$ .252	.820	.747	4	5	$\frac{1}{8}$	14	$\frac{11}{32}$	4,050	$\frac{11}{32}$	11,650	$\frac{1}{2}$	Same as above, except crack $\frac{1}{2}$″ on both sides of hole.
1.....	$\frac{3}{8}$ .370	.874	.770	4	5	$\frac{1}{8}$	12	$\frac{13}{32}$	5,700	$\frac{3}{32}$	17,415	$\frac{15}{32}$	Three good threads left in plate; bolt pulled through; cracked $\frac{3}{4}$″ on two sides of hole.
11...	$\frac{3}{8}$ .368	.874	.770	4	5	$\frac{1}{8}$	12	$\frac{3}{8}$	5,690	$\frac{1}{8}$	18,000	$\frac{1}{2}$	Same as above, except cracked $\frac{1}{2}$″ on two sides of hole.
11...	$\frac{3}{8}$ .369	.874	.770	4	5	$\frac{1}{8}$	12	$\frac{25}{64}$	6,000	$\frac{3}{32}$	18,475	$\frac{7}{16}$	Same as above, except cracked $\frac{3}{4}$″ on two sides of hole.
1.....	$\frac{1}{2}$ .495	1.014	.908	4	5	$1\frac{1}{4}$	12	$\frac{13}{32}$	12,500	$\frac{9}{64}$	29,545	$\frac{3}{8}$	No cracks around hole; head and thread stripped on bolt; threads in plate good.
11...	$\frac{1}{2}$ .497	1.014	.908	4	5	$1\frac{1}{4}$	12	$\frac{7}{16}$	13,500	$\frac{1}{8}$	29,265	$\frac{11}{32}$	
111..	$\frac{1}{2}$ .500	1.014	.908	4	5	$1\frac{1}{4}$	12	$\frac{13}{32}$	14,000	$\frac{11}{32}$	28,875	$\frac{3}{8}$	
1.....	$\frac{1}{4}$ .250	.817	.747	5	5	$1\frac{3}{32}$	14	$\frac{3}{8}$	2,750	$\frac{1}{4}$	9,960	$\frac{25}{32}$	Head and thread stripped and bolts pulled through; $\frac{3}{8}$″ cracks on two sides of hole.
11...	$\frac{1}{4}$ .248	.817	.747	5	5	$1\frac{3}{32}$	14	$\frac{3}{8}$	3,915	$\frac{11}{32}$	11,100	$\frac{11}{16}$	Same as above, except $\frac{1}{8}$″ crack on two sides of hole.
111..	$\frac{1}{4}$ .251	.817	.747	5	5	$1\frac{3}{32}$	14	$\frac{3}{8}$	3,000	$\frac{1}{4}$	10,900	$\frac{11}{16}$	Same as above, except $\frac{3}{8}$″ crack on two sides of hole.

1.....	3/8 .372	.872	.770	5	5	1 5/32	12	3/8	4,500	3/32	17,520	9/16	Head and thread stripped and pulled through; 3 threads left in plate; 1/8″ cracks on two sides of hole.
11...	3/8 .368	.872	.770	5	5	1 5/32	12	3/8	5,000	7/64	18,410	9/16	Same as above, except small cracks all around hole.
111..	3/8 .362	.872	.770	5	5	1 5/32	12	13/32	5,500	5/32	17,365	5/8	Same as above, except 3/4″ cracks on two sides of hole.
1.....	1/2 .495	1.012	.908	5	5	1 1/4	12	15/32	14,650	(*)	28,000	17/32	Head and threads stripped and bolt pulled through; threads in plate uninjured; cracks all around hole.
11...	1/2 .492	1.012	.908	5	5	1 1/4	12	15/32	14,500	3/8	29,350	5/8	Bolt broke.
111..	1/2 .492	1.012	.908	5	5	1 1/4	12	15/32	15,000	(*)	29,100	1/2	Same as first, except cracks around hole from 1/8″ to 1″.

* Strain not reached.

All stay-bolts in this table were screwed and riveted; over heads formed with button-head set.

TABLE C.

Copper plates and iron screw stay-bolts from bar No. 5. Tensile strength, 56,683 *pounds per square inch.*

Number and mark on specimen.	Thickness of boiler-plate.	Diameter of stay-bolt outside of thread.	Diameter of stay-bolt inside of thread.	Distance from center to center of supporting bolts.	Number of threads left through for riveting.	Mean diameter of head after riveting.	Number of threads on bolt to the inch.	Thickness of rivet-head at the crown.	Plate commenced to bulge at—	Bolt or plate gave way at—	Total bulge of plate after rupture.	Remarks.
	Inches.	*Inches.*	*Inches.*	*Inches.*		*Inches.*		*Inches.*	*Lbs.*	*Lbs.*	*Inches.*	
1.......	.242	.830	.745	4	5	$1\frac{1}{8}$	14	$\frac{5}{16}$	2, 000	7, 210	$\frac{3}{4}$	Heads pulled off and bolts pulled out, leaving threads in plate and on bolt but little injured; cracks in plates, back about $\frac{1}{4}''$ from edge of holes.
11.....	.248	.830	.745	4	5	$1\frac{1}{8}$	14	$\frac{5}{16}$	1, 800	8, 040	$\frac{15}{16}$	
111....	.240	.830	.745	4	5	$1\frac{1}{8}$	14	$\frac{5}{16}$	1, 900	7, 550	$\frac{13}{16}$	
1.......	.373	.830	.744	4	5	$1\frac{1}{8}$	14	$\frac{11}{32}$	6, 000	12, 400	$\frac{5}{8}$	Same as above, except cracks on opposite sides of hole, $\frac{1}{4}''$ back.
11.....	.373	.830	.744	4	5	$1\frac{1}{8}$	14	$\frac{11}{32}$	5, 500	11, 240	$\frac{3}{4}$	Same as above, except cracked slightly all around the hole
111....	.373	830	.744	4	5	$1\frac{1}{8}$	14	$\frac{9}{32}$	5, 000	11, 850	$\frac{11}{16}$	
1.......	.428	.877	.768	4	5	$1\frac{3}{16}$	12	$\frac{13}{32}$	7, 350	14, 950	$\frac{11}{16}$	Same as above, except no cracks around the hole.
11.....	.428	.877	.768	4	5	$1\frac{5}{32}$	12	$\frac{3}{8}$	6, 750	14, 675	$\frac{3}{4}$	
111....	.428	.877	.768	4	5	$1\frac{1}{8}$	12	$\frac{13}{32}$	6, 500	14, 410	$\frac{3}{4}$	Same as above, except slight cracks all around the hole.

1.......	.495	1.020	.908	4	5	$1\frac{1}{4}$	12	$\frac{15}{32}$	7,650	18,600	$\frac{23}{32}$	Bolt pulled out, leaving all the threads on bolt and in plate good; slight cracks around holes.
11.....	.495	1.020	.908	4	5	$1\frac{1}{4}$	12	$\frac{15}{32}$	8,000	18,600	$\frac{3}{4}$	Same as above, except two cracks on opposite sides of hole.
111....	.495	1.020	.908	4	5	$1\frac{1}{4}$	12	$\frac{7}{16}$	8,000	20,400	$\frac{3}{4}$	Same as above, except slight cracks all around the hole.

All the stay-bolts in this table were screwed in and riveted over, the heads being formed with a button-head set.

TABLE C 1.

Copper boiler-plates; iron screw stay-bolts (bolts from No. 5 bar). Tensile strength, 56,683 *pounds per square inch.*

Number and mark on specimen.	Thickness of boiler-plate.	Diameter of stay-bolt outside of thread.	Diameter of stay-bolt inside of thread.	Distance from center to center of supporting bolts.	Number of threads left for riveting.	Mean diameter of head after riveting.	Number of threads on bolt to the inch.	Thickness of rivet-head at the crown.	Plate commenced to bulge at—	Bulge of plate at double the strain at which commenced.	Bolt or plate gave way at—	Total bulge of plate after rupture.	Remarks.
	Inches.	*Inches.*	*Inches.*	*Inches.*		*Inches.*		*Inches.*	*Lbs.*	*Inches.*	*Lbs.*	*Inches.*	
1	$\frac{1}{4}$ .255	.828	.746	4	5	$1\frac{1}{8}$	14	$\frac{3}{8}$	3, 800	$\frac{9}{16}$	8, 940	$\frac{13}{16}$	Bolt pulled out; head slightly stripped; threads in hole slightly injured; cracks from $\frac{3}{8}''$ to $\frac{1}{2}''$ around hole.
11 ...	$\frac{1}{4}$ .255	.828	.746	4	5	$1\frac{1}{8}$	14	$\frac{11}{32}$	3, 355	$\frac{1}{2}$	8, 560	$\frac{25}{32}$	
111..	$\frac{1}{4}$ .255	.828	.746	4	5	$1\frac{1}{8}$	14	$\frac{11}{32}$	3, 620	$\frac{13}{32}$	9, 110	$\frac{3}{4}$	
1.....	$\frac{3}{8}$ .375	.879	.788	4	5	$1\frac{1}{8}$	12	$\frac{7}{16}$	6, 340	$\frac{23}{32}$	13, 800	$\frac{21}{32}$	Bolts pulled out; head partly stripped; threads in hole damaged; cracked around hole from $\frac{1}{2}''$ to $\frac{5}{8}''$ back.
11 ...	$\frac{3}{8}$ .375	.879	.788	4	5	$1\frac{1}{8}$	12	$\frac{3}{8}$	5, 700	$\frac{23}{32}$	13, 655	$\frac{3}{4}$	
111..	$\frac{3}{8}$ .375	.879	.788	4	5	$1\frac{1}{8}$	12	$\frac{3}{8}$	6, 400	$\frac{23}{32}$	13, 410	$\frac{11}{16}$	
1.....	$\frac{1}{2}$ .501	1.006	.912	4	5	$1\frac{1}{4}$	12	$\frac{29}{64}$	12, 200	Not reached.	19, 310	$\frac{5}{8}$	Bolts pulled through; head partly stripped; threads in hole damaged; small cracks all around hole of 1 1 1 plate; no cracks in the others.
11 ...	$\frac{1}{2}$ .501	1.006	.912	4	5	$1\frac{1}{4}$	12	$\frac{29}{64}$	11, 075		20, 310	$\frac{11}{16}$	
111..	$\frac{1}{2}$ .501	1.006	.912	4	5	$1\frac{1}{4}$	12	$\frac{15}{32}$	13, 200		20, 425	$\frac{21}{32}$	
1.....	$\frac{1}{4}$ .257	.827	.749	5	5	$1\frac{3}{32}$	14	$\frac{11}{32}$	2, 500	$\frac{1}{2}$	7, 115	$\frac{7}{8}$	Bolt pulled out; stripped but little of head, but none of threads on bolt; plate cracked $\frac{7}{8}''$ on each side of hole.
11 ...	$\frac{1}{4}$ .257	.827	.749	5	5	$1\frac{1}{8}$	14	$\frac{11}{32}$	2, 350	$\frac{33}{64}$	8, 855	1	Head stripped and thread slightly injured on bolt; small cracks around hole.
111..	$\frac{1}{4}$ .257	.827	.749	5	5	$1\frac{3}{32}$	14	$\frac{11}{32}$	2, 680	$\frac{9}{16}$	8, 600	$\frac{15}{16}$	

1.....	$\frac{3}{8}$ .380	.884	.791	5	5	$1\frac{1}{8}$	12	$\frac{3}{8}$	6, 300	$\frac{17}{32}$	12, 835	$\frac{7}{8}$	Bolts pulled through; head partly stripped; threads in hole damaged; small cracks around holes in 1 and 1 1 plates; no crack in 1 1 1 plate.
1 1 ...	$\frac{3}{8}$ .380	.884	.791	5	5	$1\frac{1}{8}$	12	$\frac{13}{32}$	4, 875	$\frac{5}{8}$	13, 140	$\frac{7}{8}$	
1 1 1..	$\frac{3}{8}$ .380	.884	.791	5	5	$1\frac{1}{8}$	12	$\frac{3}{8}$	5, 315	$\frac{11}{16}$	13, 295	$\frac{15}{16}$	
1.....	$\frac{1}{2}$ .502	1.005	.923	5	5	$1\frac{1}{4}$	12	$\frac{15}{32}$	8, 750	$\frac{23}{32}$	19, 000	$\frac{15}{16}$	Bolts pulled through; head partly stripped; threads in hole damaged; no cracks around holes.
1 1 ...	$\frac{1}{2}$ .502	1.005	.923	5	5	$1\frac{1}{4}$	12	$\frac{7}{16}$	8, 350	$\frac{5}{8}$	19, 900	$\frac{3}{4}$	
1 1 1..	$\frac{1}{2}$ .502	1.005	.923	5	5	$1\frac{1}{4}$	12	$\frac{7}{16}$	8, 460	$\frac{11}{16}$	19, 800	$\frac{23}{32}$	

All stay-bolts in this table were screwed and riveted over; heads formed with button-head set.

TABLE D.

Copper plates and copper screw stay-bolts.

Number and marks on specimens.	Thickness of boiler plate.	Diameter of stay-bolt outside of thread.	Diameter of stay-bolt inside of thread.	Distance from center to center of supporting bolts.	Number of threads left for riveting.	Mean diameter of head after riveting.	Number of threads on bolt to the inch.	Thickness of rivet-head at the crown.	Plate commenced to bulge at—	Bulge of plate at double the strain at which commenced.	Bolt or plate gave way at—	Total bulge of plate after rupture.	Remarks.
	Inches.	*Inches.*	*Inches.*	*Inches.*		*Inches.*		*Inches.*	*Lbs.*	*Inches.*	*Lbs.*	*Inches.*	
1.....	.244	.825	.745	4	5	1 1/8	14	3/8	2,000	....	7,900	17/32	Bolts pulled out stripping part of head, and leaving threads in hole uninjured; slight cracks around holes.
1...	.241	.825	.745	4	5	1 1/8	14	3/8	2,000	....	7,875	23/32	
11..	.250	.825	.745	4	5	1 5/32	14	5/16	1,800	....	7,750	17/32	
1.....	.373	.828	.746	4	5	1 3/32	14	11/32	3,750	....	11,375	23/32	Bolts pulled out, head stripped off; all threads in hole injured; slight cracks around hole.
11...	.373	.828	.746	4	5	1 1/8	14	11/32	4,000	......	11,000	21/32	
111..	.373	.828	.746	4	5	1 1/8	14	11/32	4,500	....	11,425	5/8	Same as above, except no cracks around hole.
1.....	.419	.878	.767	4	5	1 3/16	12	3/8	6,550	....	13,525	21/32	Bolts pulled out, heads stripped; all threads in hole left good; no cracks around hole.
11...	.423	.878	.767	4	5	1 1/8	12	7/16	5,150	....	14,100	3/4	
111..	.425	.878	.767	4	5	1 5/32	12	13/32	6,000	....	14,125	23/32	Same as above, except slight cracks around hole.
1.....	.501	1.010	.907	4	5	1 1/4	12	7/16	7,650	....	19,900	23/32	Bolts pulled through, heads stripped; all threads left good in hole but one; crack around hole.
11...	.503	1.010	.907	4	5	1 1/4	12	13/32	8,000	....	17,750	21/32	
111..	.504	1.010	.907	4	5	1 1/4	12	7/16	9,000	.. ....	19,275	21/32	

Steel plate and iron bolts No. 1 1 1 1 1 *bar. Tensile strength of stays* 56,683. *Stays riveted with button-heads.*

Number and marks on specimens.	Thickness of boiler plate.	Diameter of stay-bolt outside of thread.	Diameter of stay-bolt inside of thread.	Distance from center to center of supporting bolts.	Number of threads left for riveting.	Mean diameter of head after riveting.	Number of threads on bolt to the inch.	Thickness of rivet-head at the crown.	Plate commenced to bulge at—	Bulge of plate at double the strain at which commenced.	Bolt or plate gave way at—	Total bulge of plate after rupture.	Remarks.
1.....	1/4 .251	.855	.765	4	5	1 1/8	14	3/8	4,900	5/16	15,320	1/2	Heads stripped, bolts pulled through, threads left good in hole; no cracks around hole.
11...	1/4 .248	.850	.765	4	5	1 1/8	14	3/8	4,500	9/32	17,515	9/16	
111..	1/4 .251	.851	.765	4	5	1 1/8	14	3/8	4,600	9/32	16,575	19/32	

1.....	$\frac{1}{4}$ .251	.856	.764	5	5	$1\frac{3}{32}$	14	$\frac{3}{8}$	3, 200	$\frac{5}{32}$	15, 550	$\frac{3}{4}$	Do
11...	$\frac{1}{4}$ .254	.853	.764	5	5	$1\frac{1}{8}$	14	$\frac{3}{8}$	3, 450	$\frac{11}{64}$	16, 500	$\frac{3}{4}$	
111..	$\frac{1}{4}$ .250	.853	.764	5	5	$1\frac{3}{32}$	14	$\frac{3}{8}$	3, 210	$\frac{5}{32}$	15, 150	$\frac{23}{32}$	

All bolts in this table were screwed and riveted over; the heads being formed with a button-head set.

O

2A

PL

7

PI

8F

X

10

PL

22

LATE 27

34D

35 E